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ON THE

EARLY STAGES OF TEREBRATULINA SEPTENTRIONALIS.

BY EDWARD S. MORSE, PH.D.,

PROFESSOR OF COMPARATIVE ANATOMY AND ZOOLOGY IN BOWDOIN COLLEGE.

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From the Memoirs of the Boston Society of Natural History, Vol. II.

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II. On the Early Stages of Terebratulina septentrionalis (Couthouy.)

By Edward S. Morse.

Read October 20th, 1869.

THERE is hardly a group among the lower animals (if we consider the relatively small number of species represented by it) that has attracted the attention of so many naturalists as the Brachiopoda. The names of Cuvier, Owen, Vogt, Huxley, Hancock, Gratiolet, Lacaze-Duthiers, Bouchard-Chantereaux, Müller, Davidson, Carpenter, King, d'Orbigny and a host of others, are sufficient evidence of the interest felt in a group whose organization links them so closely with the past.

The desire to interpret through a knowledge of its living forms the many species which are now extinct, as well as to ascertain the relations it bears to the other divisions of the animal kingdom; the contemplation of a group whose maximum development in genera and species was attained in the Devonian age, though its representatives are strewn through the rocks of all ages since the dawn of life upon the globe; the remarkable fact that among the earliest forms of organic life known, are genera whose species can hardly be distinguished from present existing forms, all explain the attractions its study has afforded alike to Zoologists and Palæontologists.

The splendid memoirs upon the Brachiopoda by some of the authors just mentioned, more particularly those of Albany Hancock,[1] Vogt and Gratiolet, offer but little encouragement to one entering the field with the expectation of gleaning anything new. While, however, the anatomy and histology of the adult animal of several species has been carefully worked up, little or nothing has been done toward elucidating the embryology, or the early stages of the class. Fritz Müller[2] has given in a short note a description and two figures of what he considers an early stage of a species of *Discina*, and Lacaze-Duthiers[3] has made some extremely interesting observations on the embryo of *Thecidium*. Aside from these two papers, we know of nothing whatsoever relating either to the embryology or the early stages of the Brachiopoda. The importance and necessity of some information regarding the embryology of these animals has been urged by many writers, for it was believed that the relations between them and the Polyzoa, as urged by Agassiz, Milne Edwards, Huxley, Hancock, Dana and others, would be verified, when the development of Brachiopoda was known. In this path of inquiry the investigator will find an open field.

For a long time I have been interested in the relations of the class under consideration,

[1] On the organization of the Brachiopoda. Philosophical Transactions of the Royal Society, London, 1858, vol. CXLVIII, part 2.

[2] Archiv für Anatomie Reichart et Du Bois Raymond, 1860, p. 72.

[3] Histoire de la Thecidie. Annales des Sciences Nat. 4th series, tome XV, p. 262.

and in an early paper entitled "Hæmal and Neural regions of Brachiopoda,"[1] and later, in a paper on the "Classification of Mollusca, based on the principle of Cephalization,"[2] urged the intimate relations existing between the Brachiopoda and Polyzoa. With the hopes of learning something about the early stages of one of our native species of Brachiopods, I visited Eastport, Maine, in the early part of June, 1869, and this communication embraces a summary of the incomplete observations there made; incomplete, as I was unable to secure any data on the embryology of the species. At the outset my microscope proved altogether inadequate to the work before me, though the minute size of the objects examined, coupled with the complicated texture of the shell through which the soft parts had to be observed, rendered the work, at the best, laborious and difficult. In every case, however, the figures given in the accompanying plates are correct transcripts of the drawings made from the animal: in no instance is there given any combination of several unfinished sketches to make a more intelligible, or perfect whole. This will explain the absence of detail and completeness in many of the figures presented; at the same time it is believed that the outlines will be more valuable from the fact that they are not schematic or composite.

For a clear exposition of the organization of the Brachiopoda, I would refer to the exhaustive memoir of Albany Hancock above referred to, a memoir which justly merited the honor conferred upon him in the award of the Royal medal.

On the early stages of Terebratulina septentrionalis Couthouy.[3] The specimens upon which the following examinations were made, were dredged in fifteen fathoms of water in the harbor of Eastport, Maine, in the first week of June, 1869. The species occur in great numbers, at various depths, and have also been collected at low tide mark, by Dr. Stimpson and Prof. Verrill. The specimens were found attached to stones brought up in the dredge, and also adhering to the lower valve of adult individuals, generally near the peduncle. An examination of adult individuals showed that while the ovaries in some specimens were empty, in others they were fully charged; in some the ovaries would be partially empty, in others the ovaries of one side would be nearly empty, while those of the other side would be quite full. Specimens collected by Prof. Verrill in August, were found with eggs; and eggs were also noticed in specimens less than three sixteenths of an inch in length. The eggs, fig. 1, were generally kidney-shaped, though very irregular as to form and size; they were spermaceti white in color, and opaque, though having a central area, translucent, and apparently depressed. In general outline they suggest the kidney-shaped eggs of *Fredericella*. No intermediate stage was observed between the ovarian egg and the stage represented in fig. 2. This form recalled the general proportions of *Argiope* and *Megerlia*, in being transversely oval, in having the hinge margin wide and straight, and in the presence of a proportionately wide foramen. This stage was exceedingly minute, and only two individuals were discovered; they were attached to the rock, resting on the broad hinge area; nothing could be traced of the structure, except an appearance of granular contents, as indicated in the figure; the shell showed nothing of

[1] Proceedings Boston Society Natural History, vol. IX. 1862.

[2] Proceedings Essex Institute, Salem, vol. IX, part 6 1865. Also reprinted in American Journal Science and Arts, vol. XLII, no. 124. 1866.

[3] A brief resumé of this paper was published in the American Naturalist, Sept. no., vol. III, 1869. Since reprinted in American Journal of Science and Arts for Jan., 1870.

The general results were communicated at the 18th Annual Meeting of the American Association for the Advancement of Science, Aug., 1869.

the scale-like structure so characteristic in later stages. Between this stage and the next, fig. 3, the shell rapidly elongates, while the hinge margin remains nearly the same in width; this is also shown in the concentric lines of growth seen faintly on the surface, indicating a rapid increase in the length of the shell, while no corresponding increase takes place in the widening of the hinge margin. The peduncle is longer than the shell, having distinct walls apparently enclosing a clear interspace, the end slightly dilating and forming a pear-shaped adhering disk. The structure of the shell, of which more will be said in subsequent pages, showed clearly the scale-like structure, with the cæcal tubules of the pallial lobes perforating it. The anterior margin of the pallial lobes gave rise to seven setæ of variable lengths, all of them projecting forward. These setæ, in nearly all instances, were clothed with desmids, and were probably available in attracting sustenance to the animal; they resembled in structure the setæ of the adult, as figured by Hancock, and the longest of them was as long as the shell. The future position of the calcareous loop was indicated by a strongly arched process midway the length of the shell, from which sprang six short and stout cirri, all of them curving towards the mouth, which occupied the centre of the base from which the cirri sprang. The digestive sac hung from the mouth, and was twice as long as broad, having a strong constriction in the centre, forming two chambers, the lowermost one being globular in shape, and having its walls colored a light reddish-brown, this colored portion evidently indicating hepatic cells. The cavity next the mouth indicates the stomach, while the lowermost cavity indicates the future intestine, or cul de sac. The cirri moved frequently, and in various directions, though generally performing a grasping motion, as if securing some bit of food, imitating precisely the movement of the cirri in Polyzoa, and this resemblance was more complete from the fact that the tentacles were densely clothed with cilia (fig. 4), and their movements caused visible currents in the water. The two cavities of the digestive sac were also ciliated, and little pellets of food were seen rapidly circulating back and forth from one cavity to the other. The cavities were alternately dilating and contracting, and assumed the forms represented in figs. 5, 6 and 7. At this stage the lower cavity of the digestive sac was diverted to the larger valve, as represented in fig. 4.

In this stage, and several succeeding stages, the outline of the shell is remarkably like that of *Lingula*, and this resemblance is more striking from the proportionately long peduncle.

In another stage, numerous irregular shaped calcareous spiculæ lined the outer margin of the cirri, while the future position of the calcareous loop, or crura, was indicated by a row of irregular shaped spiculæ, the correct forms of which are given in fig. 15.

Fig. 16 represents portions of two cirri more highly magnified, in which correct outlines are given of the spiculæ. It is to the presence of these calcareous particles that we must account for a certain rigidity noticed in the texture of the cirri. In these slightly advanced stages, the peduncle becomes much shorter in proportion to the length of the shell, though the shell presents the same lingula-like form, differing, however, from *Lingula* in the much greater length of the neural valve, which is always perforated and rostrated from the outset.

In all these stages the peduncle has very slight adhesion to the rock, or whatever substance it may be attached to, in this respect differing greatly from the adult, which often requires great force to detach it, frequently leaving the peduncle separated from the body, and adhering to the rock.

In figs. 8 and 9 are given side views of the shell at this period. The flatness of the valves will be observed, again resembling *Lingula* in this respect; the under valve is much flatter than the upper one. I was fortunate in observing an individual at this age in motion. The animal whirled quickly on its peduncle; when at rest the shells were always closed, and rested on the rock; from this position it turned slowly more than half way round, raising the body at the same time almost erect; this movement being completed, the valves would very slowly open, and the cirri expand as if to perform a grasping motion; in no case, however, were they projected beyond the margin of the valves. The cilia lining the cirri produced gentle currents in the water. In this position, with the valves widely open and cirri expanded, the animal would remain motionless for twenty or thirty seconds, and then, with an abrupt closing of the valves, suddenly assume its first position. These two positions are represented in fig. 10, where the animal is seen from the side, and in fig. 11, where it is seen from above. The outline marked A represents the shells closed and at rest, while B represents the shells open; the line of arrows indicates the direction of the rotatory movement.

In watching these motions for a long time, one could not help being impressed with the fact that caution was evidently indicated in the slow and careful movements made in elevating and opening the shell, while the prompt closing of the valves, and the alert manner in which the animal regained its first position seemed to show that food had been secured, and further caution was unnecessary.

In another stage, fig. 12, the tentacles were seen of various lengths, some of them just budding from the lophophore. A fold upon each side of the stomach was first noticed; these folds are the first appearance of the liver. At this time the hepatic folds expand and contract independently of each other (fig. 14).

In fig. 13 another view of the same individual is given, where the upper portion of the digestive sac, or that portion which answers to the œsophagus and stomach, is in a contracted state, while the lower portion is widely expanded. A peculiar constriction appears at times between the two chambers of the digestive sac, which recalls the cardiac or œsophageal valve, as seen in the Phylactolæmatous Polyzoa; it has no coniform projection into the stomach, and really appears more distinctly as an annular dilatation. All traces of it disappeared during certain expansions and contractions of the gastric walls. All portions of the sac and the lateral folds were strongly ciliated, and the food, now gathered into round pellets, and again scattered in granules, was violently impelled back and forth.

In fig. 4, the cirri are shown, clothed with cilia; in fig. 12 the cirri are shown plain, while the cilia are shown lining the digestive sac. In fig. 15 only the calcareous spiculæ are shown; but in all these cases each possesses the characters of the others, which for clearness are shown singly.

Fig. 17 exhibits the only example where the soft parts are drawn from an alcoholic specimen. In this example is first seen a set of muscles, rendered visible by their contraction in alcohol, and consequent greater density. They are probably the divaricator muscles, though somewhat in advance of what their position would be in the adult state.

Owing to the contraction of the digestive sac, its diverticular cavities are sharply defined, and the globular appearance of the lower cavity is marked. In another alcoholic specimen of the same age, a band, evidently one of the lateral gastro-parietal bands, was

made out. As this could not be verified in other specimens of the same age, the figure is not given.

A still more advanced stage is shown in fig. 21. The shell is now becoming proportionately broader, and the cirri increase in number, though still forming a simple circle around the mouth. The crura have also begun to form.

In fig. 22 a considerably more advanced state is shown. The valves have been forcibly separated, and the smaller one is thrown back. The cirri are more numerous, numbering thirty-one; two of them are seen encroaching upon the circular lophophore, and at this stage the lophophore has begun to assume its hippocrepian character.

The crura (*cr*) are plainly seen supporting the crown of cirri, and the liver already shows the first indications of its differentiations into the peculiar cæcal ramifications which become so numerous in the adult; and at this stage is seen the division of each lateral portion of the liver into a dorsal and ventral lobe; a lateral lobe is shown in fig. 23. It will be seen that the liver is divided into a series of cæca, though these are united.

The divaricators (*d*) are completely formed, and between these two muscles is seen the lengthened intestine (*i*), the blind extremity of which is held firmly to the shell by a membrane, called by Hancock the ventral mesentery.

The appearance of the shell at this stage is represented in fig. 26. Radiating ribs, to the number of fifteen, ornament the shell. It will be seen by this figure, that the setæ correspond in growth and position to the radiating furrows, and this observation is also made by Hancock in his examination of the adult. A well defined concentric line seems to indicate the earlier lingula-shaped shell, and though no ribs appear in the earlier stages, they are defined upon this area afterward, and it would appear from this that the ribs are formed on the inner surface, and that the setæ direct and induce the furrow. The lobes of the liver (*l*), and the peduncle (*p*) and peduncular capsule, are shown in this figure.

In fig. 24 a stage still more advanced is given; the valves are thrown back, disclosing the stomach and intestine suspended from the calcareous loop. The crura (*cr*) are well defined, and the ventral mesentery (*vm*) is more distinctly seen in this figure. Two lateral bands are seen holding the stomach in position; and these appear to be attached to the crura, though they probably pass by them, and become attached to the hæmal valve. These are the lateral gastro-parietal bands first described by Huxley.

The walls of the blind intestine are yet light brownish in color, as in the Phylactolæmata, and, as before remarked, are hepatic. A kidney-shaped area is faintly defined on the neural valve. A portion of this outline indicates the point of attachment of the perivisceral wall.

In fig. 24*a* an enlarged view of the digestive sac and adjacent parts of fig. 24 is shown. The liver in this stage communicates with the stomach by large openings on each side, and fine granules were seen rapidly circulating to and fro, from the liver to the stomach. The fæces, rolled into a spiral and pyriform shape, were constantly in motion by the action of the cilia lining the stomach. This mass was frequently urged toward the mouth before it was finally discharged. The passage of the fæces through the mouth was repeatedly witnessed; though after the careful investigations of Huxley, Hancock, Lacaze-Duthiers and Gratiolet, no further proof is needed of the absence of an anal outlet to the intestine of this, and allied species.

The experiments of Mr. Hancock, such as bursting the intestines under a compressor,

were performed on many living adult specimens, yet in no case was the slightest evidence of an anal outlet observed.

Fig. 25 represents a stage but slightly advanced from fig. 24. The cirri are more numerous, but still spring from a circular lophophore.

Fig. 27, plate II, represents a considerably advanced stage, in which the lophophore, before circular, has rapidly assumed its hippocrepian character; rapidly, — since forms nearly of the same size show no marked indications of change, for in one example we may have a circular lophophore, or one showing but slight indentation, while in another example, hardly differing in size, we have the lateral processes well advanced in development. It is possible that we may have here a feature observed by Fritz Müller in the young *Discina* described by him; he mentions the remarkable fact of having repeatedly captured free swimming young which had evidently advanced further in their development than the oldest of those which had already fixed themselves. It will be noticed that in this stage (fig. 27) the cirri stand erect upon the arms, that is pointing towards the anterior margin of the shell, and that the arms are not deflected. This stage of the lophophore vividly recalls the hippocrepian forms among the Polyzoa, such as *Plumatella*, *Cristatella*, *Lophopus* and others.

The liver now shows its adult characters in having its ramified cæca separated, and not adhering by their walls in one mass. In this early condition it resembles the liver of Thecidium, as described and figured by Lacaze-Duthiers.

Fig. 28 represents a stage where the arms become deflected; as yet no central process of the lophophore is developed; the mouth is very large, and that margin of it not bearing cirri is very pliant in its movements.

In the next stage (fig. 29) the arms are more deflected and make a sharper curve in their approach together, and the central process of the lophophore is indicated by that portion forming the base of the inner curve, developing into two prominences. The free lip is seen in irregular curves, and these changed with every movement of the parts.

Fig. 30 represents a slightly more advanced stage, where the central processes of the lophophore are more developed. The free lip is here seen thrown broadly back, disclosing a capacious mouth, within which are seen two blunt projections, though in another view of the mouth (fig. 31) only one projection was observed. The free lip seemed to perform all the functions pertaining to the epistome in the higher Polyzoa, and we find it on the inner bend of the arms, as in the Polyzoa, though not occupying the same homological position in regard to the flexture of the intestine. It will be noticed that in all these stages the cirri are comparatively thick.

In the stage represented by fig. 32, the cirri become more attenuated and increase rapidly in number; the central process is more advanced, though not yet thrown into a vertical spiral, as in the adult, and the mouth has lost the broad reflected character of the lip, which it possessed in the earlier stages, though the free lip has yet considerable pliancy, as seen in figs. 33 and 34, where other views of the same mouth are presented. For the first time now appears another adult character, in the apparent decrease in the length of those cirri in the median line of the mouth.

In figs. 35, 36 and 37, different aspects of the mouth of an adult individual are shown; figs. 35 and 36 representing the outline of the mouth alone, while in fig. 37 the cirri are shown. In these three views the oral tubercle (*ot*), as it may be called, is strongly

marked. The same projection is represented in the mouth of *Thecidium Mediterraneum*, as figured by Lacaze-Duthiers. A singular lunate groove, running parallel with the free lip, is indicated in the figures, which may be called the oral groove (*og*). It seems more like a wrinkle caused by the expansion of the free lip, though its limits are well defined and the furrow is quite deep.

The independent movements of the cirri are shown in fig. 37; these are just as pliant in their movements as in those of the extreme young, and at all times recall the motions of the cirri in the Polyzoa.

Structure of the Shell. In the younger stages of the shell the peculiar scale-like structure may be studied to the best advantage. The scales are few in number, but slightly overlapping, and form a layer quite distinct from the outer layer, which appears to be homogeneous, save the concentric lines of growth appearing like rows of oblong and flattened nodules. The terminal portions of the pallial cæca within or upon this outer layer, are brown in color and distinctly granulated. I failed to make out anything satisfactory regarding the character of these peculiar parts. In a few doubtful cases I thought I saw one or two tubules radiating from the terminal ends of the cæca, and in fig. 38, A, one observation is represented. It will be seen by this that the tubules radiate from the largest diameter of the cæca, and not from the periphery of the granulated disk, and this is in accordance with the admirable observations made by King.[1] The scales do not appear to encroach upon the walls of the cæca.

Fig. 38 shows a small fragment of the shell at an early stage; portions of five scales are here seen forming the inner layer of the shell. In the earlier stages, when they are large and few in number, the scales are flat; now and then showing a raised line caused by the encroachment of two superincumbent scales, between which the under scale is closely adjusted. This may be seen in fig. 39, and better in fig. 40, where the ends of the scales are broken, and show in section; also in fig. 41, where, in a later stage, they become more numerous; here the terminal ends of five scales are shown in juxtaposition.

In fig. 42 a portion of the anterior margin of one valve is shown. The newly formed scales are just indicated near the border, beyond which the outer layer projects.

Fig. 43 represents two scales from a stage still more advanced; here the numerous lines upon the scales indicate their closer aggregation. As the shell increases in age, the scales become more attenuated, and now the scale is diverted wherever it encounters a cæcal process, and forms a yoke or loop around it.

In fig. 15, plate I, a few spiculæ at the base of the cirri mark the commencement of the calcareous loop. At a later stage the spiculæ increase rapidly in number, and finally anastomose, appearing as in fig. 44. The scales composing the base of the crura are acicular in shape, and run parallel with the crural axis. In adult specimens the scales of the crural supports resemble acicular crystals, and when boiled in a solution of caustic potash, glisten and separate, resembling the fibres of asbestos (fig. 47).

Fig. 46 represents the crural process of one side, taken from a specimen less than an eighth of an inch in length. It exhibits the first stages of the loop. The acicular scales are shown at the base, while the remaining portion is made up of scales similar to those

[1] Prof. W. King, on the Histology of the Test of the Class Palliobranchiata. Transactions of the Royal Irish Academy, vol. XXIV, pt. xi, 1869.

composing the shell. From an extremely young specimen I observed these same peculiar acicular scales (fig. 45), and they probably indicate the presence of the crura.

Nothing of a satisfactory nature was made out regarding the structure of the shell in the earliest stage (fig. 2, plate I), though had the shell possessed the peculiar scale-like structure and cæcal perforations, they would have been visible.

Growth of the Shell. Figs. 18, 19 and 20, plate I, severally show portions of the hæmal valve, neural valve, and the valves connected, from an early lingula-form stage. In fig. 18, the hinge plate (*hp*) and the dental socket (*ds*) are well marked; in the earlier stages of their development the crura appear as slight projections. In fig. 19 the prominence of the so-called teeth of the shell (*te*) is given.

Fig. 20 represents the valves joined; the cæca are seen perforating the entire margin of the shell about the foramen, which is very wide and rudimentary.

On plate II a series of stages are given to show the gradual development of the crura, and parts surrounding the foramen. The upper line of figures in this series, marked N, represents the neural or ventral valve, and the lower line of figures, marked H, represents the hæmal or dorsal valve. In the youngest of these stages, figs. 48 and 49, a broad gap in the neural valve indicates the peduncular foramen. It will be seen that the shell is folded upon each side of the peduncular passage. These folds never meet in this species.

Figs. 50 and 51 show a slightly more advanced stage, the difference being mainly in the greater prominence of the crura.

In the next stage, figs. 52 and 53, the calcareous loop is well advanced, though not yet connected by a continuous shelly layer, though at all stages these portions are connected by a membrane charged with spiculæ. Figs. 54 and 55 represent similar portions of an adult shell for comparison. It will be seen that the neural process of the loop becomes connected, while the hæmal process does not become so connected, though in some specimens it closely approximates. The peduncular opening becomes more circular, and the cardinal process (*cp*), which does not appear in the earlier stages, is now present.

Figs. 56, 57 and 58 are added, to exhibit the relative outlines of the more prominent stages in the growth of the shell. Compare, also, fig. 2, plate I, where the shell is as long as it is broad, and the hinge margin represents the greatest transverse diameter of the animal. In fig. 56 the shell elongates, with the sides nearly parallel, and the peduncular opening wide and gaping. (The line accompanying the figures represents the natural size of the shell.) Fig. 57 represents a stage intermediate between the lingula form and the adult; the peduncular opening is more contracted, the sides of the shell are no longer parallel, though the hinge margin has nearly the same outline as in the first stage. Fig. 58 represents the adult shell. Here the outline assumes entirely different proportions, being nearly oval, while the hinge margin forms a sharp angle, and the foramen is quite circular.

Relations with the Polyzoa. The general affinities of the Brachiopoda with the Polyzoa, as indicated by Milne Edwards, Huxley, Hancock, Agassiz, Hyatt and others, are admitted by most zoologists.

In the preceding examinations of the early stages of *Terebratulina*, we have additional evidence of their relationship. In the evolution of the lophophore, from its circular character, surmounted by a few cirri, to that of the hippocrepian stage, we have suggested, first, the circular lophophore in the inferior, or Gymnolæmatous Polyzoa, and finally, the

bilateral lophophore of the superior, or Phylactolæmatous Polyzoa. The brachial fold, a delicate membrane bordering the lophophore, immediately within which the cirri spring, as seen in *Lingula* and *Discina*, may properly be compared to the calyx in the higher Polyzoa. Still later the presence of a distinct fold bordering the mouth, very pliant and active, may be compared as to function and position, with the epistome of the Polyzoa, though not occupying an homological position in regard to flexure of intestine. It would appear that the membranes suspending the stomach and intestine in the perivisceral cavity, have some relation to the funiculus in the Polyzoa. In *Paludicella* there are two flexible cords connecting the stomach and the endocyst, called by Allman the anterior and posterior funiculus, to which are attached respectively the ovary and testis. In *Lingula* and *Discina* we find the reproductive organs attached to bands, that connect the stomach and intestine to the perivisceral wall. In *Alcyonella* the ovary arises from the endocyst, and likewise in *Terebratulina* and allied genera we find the mantle, or endocyst, holding the reproductive organs.

The early appearance of the divaricator muscles in *Terebratulina* would justify Mr. Hyatt in his views, that these muscles represent the retractors of the Polyzoa.[1]

The combination of the stomach and intestine in their early stages, with the presence of hepatic cells lining their inner walls, and the presence also of a cardiac valve or constriction, all recall similar parts in the higher Polyzoa.

That these relations may be carried farther, there is no reason to doubt. Fritz Müller has noted in an early stage of some species of *Discina* (though from observations I have made in *Lingula pyramidata*, the embryoes examined by him are as likely to belong to this genus, as to *Discina*) several sets of setæ, which project from the body and are capable of locomotion. F. A. Smitt[2] has noticed in the development of *Lepralia Peachii*, a cluster of six bristles bent at their points, that from time to time were drawn in and again thrust out.

With propriety may also be suggested a certain parallelism between the leading groups of the Polyzoa and the Brachiopods. We have forms, like *Lepralia*, attached by one region of their shell, this shell being calcareous and exhibiting minute punctures, which have been compared to similar markings in certain Brachiopods. So among the latter group do we find forms attached, as in *Thecidium*, and some species of *Productus*; and generally the articulate Brachiopods might be compared to such forms as *Lepralia*, while on the other hand such genera as *Pedicellina*, with its long, pliant and muscular stalk, or *Loxosoma*, with a stalk highly retractile, may be compared to *Lingula*. The limits or intentions of this paper will not allow any considerations regarding the relations of the Brachiopods with the other groups of the animal kingdom. I have elsewhere[3] expressed my belief that they are true articulates, having nearer affinities with the Vermes; and in view of the above relations of the Brachiopods with the Polyzoa, it is interesting to remark

[1] A. Hyatt. Observations on Polyzoa, suborder Phylactolæmata. Proceedings Essex Institute, vols. IV, V. Salem, Mass.

[2] Om Hafs-Bryozoernas utveckling och fettkroppar. Öfversigt af Kongl. Vetenskaps-Akademiens Forhandlingar. Stockholm, 1865.

[3] The Brachiopoda, a revision of Annelida, American Journal Science, July, 1870. Reprinted in Annals and Magazine of Natural History, London, no. 33, vol. VI, 4th series.

that Leuckart has for a long time placed the Polyzoa with the Vermes, and in a new edition of the "Outlines of Comparative Anatomy," [1] Prof. Carl Gegenbaur removes the Polyzoa from the Mollusca, and associates them with the Vermes.

Explanation of Plates.

PLATE I.

Fig. 1. A few eggs in their natural position, from pallial membrane of an adult individual.

Fig. 2. Earliest stage noticed. This was attached to rock, resting upon broad hinge margin.

Fig. 3. Another stage in which the body has rapidly lengthened, and the peduncle is equal in length to the remaining portion of the animal.

Fig. 4. Stage in which a few cirri are developed with the œsophagus and stomach hanging below.

Figs. 5, 6, 7. Œsophagus and stomach of last individual, showing different conditions of expansion and contraction of the parts.

Figs. 8, 9. Partial lateral views of the shell of fig. 3.

Fig. 10. Represents the animal at rest, and in action.

Fig. 11. The same from above; the arrows indicating the direction of rotation.

Fig. 12. A state more advanced, with the liver as a simple hepatic fold on each side of the stomach.

Figs. 13, 14. Different states of contraction of incipient hepatic folds of fig. 12; and showing cardiac contraction in fig. 14, *c*.

Fig. 15. Crown of cirri to show calcareous spiculæ. [For distinctness and to simplify the drawings, the cilia clothing the cirri are only shown in fig. 4, the simple outline of cirri in fig. 12 and the calcareous spiculæ in fig. 15. It will be understood, however, that each figure possesses all the characters of the others.]

Fig. 16. Portions of two cirri highly magnified to show more plainly the form of spiculæ.

Fig. 17. Alcoholic specimen in which divaricator muscles were visible owing to contraction of the parts in alcohol. This is the only figure drawn from a preserved specimen. All the others are from life.

Fig. 18. A portion of hæmal valve.

Fig. 19. A portion of neural valve.

Fig. 20. The same portions before separation.

Fig. 21. A slightly more advanced stage, showing crown of cirri.

Fig. 22. A still more advanced stage, with hæmal valve forcibly thrown open, showing divaricator muscles with stomach between. The crown of cirri shows first indications of its bilobed character.

Fig. 23. An hepatic mass from one side; at this stage showing the first forming of cæcal folds.

Fig. 24. A stage more advanced; valves forcibly separated in which all the parts are plainly seen.

Fig. 24, A. A highly magnified view of the stomach, hepatic folds, lateral bands, etc., of fig. 24. This figure shows a fæcal mass rolled in a spiral form, in the act of being discharged through the mouth. The line bordering the upper portion of the figure indicates the inferior margin of the crural process.

Fig. 25. The hæmal valve with crown of cirri, etc.

Fig. 26. A view of fig. 22 with the valves closed.

PLATE II.

Fig. 27. A stage considerably more advanced than preceding ones, showing lophophore already bilobed, the cirri, however, not deflected. The cæcal lobules of liver few in number but separated. In fig. 23, plate I, the lobules are just indicated.

Fig. 28. Showing lophophore, with cirri deflected. The stomach and blind intestine hanging below.

Fig. 29. The arms of the lophophore more sharply bent; the central processes first indicated. The highly flexible lip is here seen in folds.

[1] Grundzüge der Vergleichenden Anatomie. Zweite ungearbeitete Auflage. Leipzig, 1870.

Fig. 30. A stage slightly more advanced than the preceding. The lip is seen thrown back, disclosing the capacious mouth.

Fig. 31. Another view of the same opening.

Fig. 32. A stage more advanced, in which the lophophore begins to assume the characters of the adult. The cirri are now more numerous and more attenuated, and the lip is not so widely reflected.

Figs. 33, 34. Showing the mouth of fig. 32 in different states of contraction.

Figs. 35, 36, 37. Views of the mouth of an adult individual, showing oral tubercle, and oral groove.

Fig. 38. Fragment of shell highly magnified, showing scales, tubules and outer layer, with lines of accretion indicated by rows of flattened, bead-like nodules.

Fig. 38, A. Exterior portion of tubule, showing radiating pores.

Fig. 39. Single scale.

Fig. 40. Single scale, broken across, and showing ridge in section.

Fig. 41. Five scales in position.

Fig. 42. Fragment of anterior portion of hæmal valve.

Fig. 43. Two scales from an adult specimen.

Fig. 44. Portion of crural process from early stage.

Fig. 45. Acicular scales from early stage.

Fig. 46. Right crural process, from early stage.

Fig. 47. Acicular scales from base of crural process of adult.

Figs. 48, 49, 50, 51, 52, 53. Portions of hæmal and neural valves of early stages showing development of crura.

Figs. 54, 55. Corresponding parts of adult, natural size.

Figs. 56, 57, 58. Outlines representing different stages from extreme young to adult, fig. 58 being natural size.

NOTE.—No means of measurement were at hand when the original studies were made. A line enclosed by a circle indicates the entire length of the shell from which the parts were drawn. Where the size is not indicated, it will be understood that the parts are from equally young stages, unless otherwise described in the explanation of plates.

EXPLANATION OF LETTERS ACCOMPANYING THE FIGURES.

m, mouth.
e, epistome.
œ, œsophagus.
s, stomach.
c, cardia.
i, intestine.
f, fæces.
vm, ventral mesentery.
l, liver.
h, hepatic cells.
og, oral groove.
ot, oral tubercle.
d, divaricator muscles.
lb, lateral gastro-parietal bands.
p, peduncle.
pa, point of attachment of peduncle.
se, setæ.
cm, pallial cæcum.
t, cirri.
g, granules passing to and fro from liver to intestine.
cr, crura.
cl, calcareous loop.
ex, external shell layer, of a chitinous nature.
in, internal shell layer, of calcareous scales.
cœ, pallial cæca.
hp, hinge plate.
cp, cardinal process.
ds, dental sockets.
fo, foramen.
te, teeth of shell.
cs, calcareous spiculæ.
cn, notch for pallial cæca.
H, hæmal valve.
N, neural valve.

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